Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

1.3
1A
9

ARS SPECIAL REPORT

LIBRARY
RECEIVED
JUL 11 1961
U. S. DEPARTMENT OF AGRICULTURE
BELTSVILLE BRANCH

A UNIVERSAL EQUATION FOR MEASURING WIND EROSION

An Aid to Conservation Farming in the Great Plains

ARS 22-69

June 1961

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

FOREWORD

ARS scientists have developed a wind erosion equation that is proving to be an important contribution to conservation farming in the Great Plains. The equation reflects the influence of the major factors known to affect wind erosion. Its usefulness in measuring a field's susceptibility to erode and for defining the practices needed to prevent erosion or to keep erosion from exceeding an insignificant rate have been established. It should ultimately take the guesswork out of conservation farming in the Great Plains by replacing generalized, observed estimates of field erodibility with quantitative measurements.

As it now stands, the equation is both useful and practical. Continuing research, which is more accurately identifying the exact role of each of the factors of wind erosion, will result in refinements that will make the equation even more useful and versatile.

County agents and other agricultural leaders should consider this report both a reference and a tool--a reference that answers most of the questions usually asked about wind erosion and a tool for use in making erodibility evaluations or in demonstrating how they are made.

Information in this report was provided by the Soil and Water Conservation Research Division, Agricultural Research Service

A UNIVERSAL EQUATION FOR MEASURING WIND EROSION--

An Aid to Conservation Farming in the Great Plains

Few regions are entirely safe from wind erosion. In the United States, the most susceptible is the Great Plains, the region that extends almost from the Mississippi River to the Rocky Mountains and from the Gulf of Mexico to Canada. Other major regions subject to this costly, needless damage are the Columbia River plains, some parts of the Pacific Southwest and the Colorado Basin, the muck and sandy areas in the Great Lakes region, and the sands of the Gulf and Atlantic seaboards.

Wind erosion occurs when winds blow across smooth, bare fields in which the soil is loose, dry, and finely divided. Its effects can be extensive and serious. During the 1930's, wind erosion damaged millions of acres in the Great Plains, many fields lost from 2 to 12 inches of topsoil, and some sandy land became sand dunes. Thousands abandoned their farms and parts of the region became the Dust Bowl, an epithet still current in our national vocabulary and still defined in almost any English language dictionary.

The Great Plains were especially susceptible because of recurring periods of drought, because wind in this region blew strongest during late winter and early spring when the least vegetation was on the land, and because fallowing and other cultural practices broke up the soil into fine particles that the wind could easily move.

The Great Plains are still susceptible to significant wind erosion losses but losses become less and less each year, even though the factors that initiate or influence erosion still operate. The lessening is due to a better understanding and appreciation of the problem--to better land use and improved farming methods whose effectiveness has been established by research. Much of this research has been done at the ARS Wind Erosion Laboratory at Kansas State University, Manhattan.

The laboratory's most recent contribution to the understanding and control of wind erosion is a universal equation for predicting a field's susceptibility to erode and for defining the controls needed to reduce this susceptibility. The equation is versatile--it can be used wherever wind erosion is a problem. Thus, Soil Conservation Service technicians and agricultural leaders generally have a potent, new tool to aid them in their conservation and education work.

MORE ABOUT THE PROBLEM

Wind erosion is seldom an individual problem. Once started, it tends to spread from field to field and from farm to farm. Well-protected fields within which soil and surface conditions preclude the initiation of erosion may be damaged by soil drift from adjacent fields.

A field's susceptibility to erode is never static. Freezing and thawing, wetting and drying, break down stable soil aggregates into erodible particles. The abrading effect of blowing particles acts similarly and sometimes destroys protective strips of vegetation and growing crops. (This

abrading effect is similar to the mechanical process of sandblasting.) Cover crops to protect fields during late winter and early spring when most erosive winds blow cannot always be established in the fall in the Great Plains because soil moisture is often inadequate.

These aspects of wind erosion show that the primary objective of conservation farming in the Great Plains is to keep the soil from blowing. If this objective is not attainable, the second best is to keep the blowing from exceeding an insignificant rate on any field. The new equation is the tool to use to determine a field's susceptibility and to define the controls needed to prevent blowing or to keep it from exceeding an insignificant rate. The fact that a field's susceptibility is seldom static should encourage frequent use of the equation throughout the Great Plains.

AN INSIGNIFICANT RATE OF SOIL MOVEMENT

An insignificant rate of soil movement is presently set at an annual soil loss of 5 tons per acre. It corresponds to a relative field erodibility (which will be explained later) of 0.1. This rate of soil loss is based on the following important considerations:

1. Maintaining adequate soil depth for lasting crop production.

2. Maintaining original soil texture by preventing soil sorting by wind.

3. Preventing direct injury to seed and crops because of the abrasive effect of blowing soil and the smothering effect of deposited soil.

4. Removing a possible health hazard to human beings and animals and a possible source of damage to home buildings, windbreaks, ponds, ditches, terraces, and other structures and installations because of air-borne dust and deposited and blowing soil.

The goal should be to reduce the rate of erosion to an insignificant quantity not exceeding 5 tons per acre per annum.

FACTORS THAT INFLUENCE WIND EROSION

The new equation is as follows: $E = IRKFCWDB$, which is a symbolic way of saying that a field's susceptibility to erode depends on eight major factors:

1. The ratio between nonerodible and erodible soil aggregates--soil cloddiness factor, I.

2. Whether the surface is bare or covered--surface cover factor, R.

3. How rough or smooth the surface is--ridge roughness equivalent factor, K.

4. The soil textural class or its inherent tendency to erode--soil abradability or stability factor, F.

5. Where the field is located geographically--wind velocity-surface soil moisture factor, C.

6. How wide the field is--field width factor, W.

7. How the field is oriented--wind direction factor, D.

8. Whether the field is protected by shelterbelts or tall stubble--the wind barrier factor, B.

Many years of investigation and many thousands of experimental tests in the laboratory and in the field were needed to identify and to establish ways of measuring these factors. The primary tools were the laboratory and portable field wind tunnels--rectangular enclosures about 3 feet by 3 feet in cross-section and from 30 to 56 feet in length in which experimental setups could be accurately established and through which streams of air could be directed and controlled.

Using wind tunnels, ARS scientists discovered the basic mechanics of wind erosion and found that the primary surface conditions that promote or retard erosion in a tunnel act similarly in large fields. These primary surface conditions are interactions of the first three factors--soil cloddiness, crop residue, and surface roughness. Thus, any field at any given time has a "wind tunnel erodibility"--a characteristic attribute that indicates its relative vulnerability or resistance to erosion.

Wind tunnel erodibility is expressed only by number. It is expressed that way because the amount of erosion obtainable in a tunnel varies not only with soil cloddiness, soil cover, and surface roughness, but also with the structural characteristics and dimensions of a tunnel. The wind tunnel erodibility is expressed in terms of soil erodibility index X_2/X_1 in which X_1 is the amount eroded when the soil contains 60 percent of nonerodible clods and X_2 is the amount eroded under the same set of tunnel and other conditions from soil containing any other proportion of nonerodible clods. Therefore no matter what units of measure are used to measure soil loss, they cancel out when wind erodibility is computed. Furthermore, for any given set of surface conditions the wind tunnel erodibility should be about the same no matter which tunnel is used in determining the erodibility.

A wind tunnel is usually shorter than a cultivated field. Because of this, the rate of soil flow in a tunnel is rapid at first but quickly diminishes. Movement ceases, often within minutes, after all erodible material on the surface is blown off. Wind tunnel erodibility is therefore based on the amount of soil removed per unit area until movement ceases.

On the other hand, due to much more abrasion than that which occurs in a tunnel, soil movement on a field does not stop as long as erosive winds blow, unless the field is unusually small. This fact necessitates evaluating the fourth factor (the soil abradability factor; see p. 5) to find a field's natural surface erodibility. Natural surface erodibility is also expressed by a number. It applies to unprotected fields within the vicinity of Garden City, Kans., (see p. 9) that are wide enough to support the maximum rate of soil flow that an erosive wind can carry.

Natural field erodibility must be modified to establish relative field erodibility if any (or all, or combinations) of the following prevail: (1) The field is protected by a shelterbelt or other barrier, (2) it is not wide enough to support the maximum rate of soil flow that an erosive wind can carry, and (3) it is not within the vicinity of Garden City, Kans. Establishing relative field erodibility, which is also expressed by a number, necessitates evaluating the remaining four factors.

Finally, based on numerous comparisons of the relative field erodibility with the depth of soil removal, the ARS scientists developed a chart

and table that can be used to convert the relative field erodibility to annual soil loss expressed in tons per acre--a readily understood system of measurement.

The following sections show how the factors that influence wind erosion are evaluated and how these evaluations are used to establish: (1) A field's wind tunnel erodibility, (2) a field's natural surface erodibility, and (3) a relative field erodibility, or susceptibility. A concluding section relates relative field erodibility to annual soil losses.

Soil Cloddiness (I)

Laboratory and field measurements and observations show that when a majority of the soil aggregates have diameters smaller than a critical minimum, soil movement is possible notwithstanding the effectiveness of some of the other factors to retard it. The critical minimum is 0.84 millimeter (a millimeter is 0.039 inch). The ideal range of clod diameters is between 0.84 and 6.40 millimeters. Clods within this ideal range resist the force of erosive winds and also shield smaller, erodible clods. Clods larger than 6.40 millimeters are also effective but they cover less area in proportion to weight than the ideally sized.

Evaluation of the soil cloddiness factor, therefore, hinges upon determining the percentage of clods in the field that have diameters greater than 0.84 millimeters. This evaluation is done by sieving four or more representative dry soil samples of 4 pounds each taken to a 1-inch depth. A hand-rotating sieve, designed and built by ARS scientists, is convenient for this purpose in the field or laboratory. Its dimensions and instructions for its use appear in Production Research Report No. 25, "Estimations of Wind Erodibility of Farm Fields."[1]

A conventional flat sieve 8 inches in diameter or larger can also be used, but each soil sample should be divided into two or more parts and sieved separately so overshaking is not necessary, which might break clods larger than 0.84 millimeter into erodible particles. The soil remaining in the sieve after each shaking is collected and weighed. The results of the weighing divided by the total weight of the samples gives the percentage of clods greater than 0.84 millimeter in diameter. Flat sieves of the given dimensions or wire screening with openings 0.84 millimeter in diameter are readily available--0.84 millimeter is one of the sieve sizes established by the National Bureau of Standards.

Crop Residue (R) and Other Surface Covers

Crop residue (stubble and growing crops undisturbed by cultivation) shields the soil and reduces wind velocity next to it. The degree of protection depends on the amount, kind, and orientation of the residue. Evaluating this factor, therefore, hinges on determining the pounds of residue per acre of land and noting its orientation and its quality.

The best way to make this determination is to collect the residue from 3 different 1-square-yard segments of representative field conditions. Any soil or foreign material clinging to the samples is washed out or otherwise

[1] A publication of the Agricultural Research Service and available from the Office of Information, United States Department of Agriculture, Washington 25, D. C.

removed. The residue is then dried and weighed. Weight of the three 1-square-yard samples in ounces, multiplied by 100, equals the quantity in pounds per acre.

Ridge Roughness Equivalent (K)

The degree of surface roughness depends on height, length, density, and orientation of vegetative cover and on size, shape, and lateral frequency of clods, ripples, and ridges. Effective roughness slows the velocity of the wind and traps moving soil particles. Small reductions in wind velocity can be quite effective since the erosive force of wind varies as the cube of its velocity. To satisfactorily fulfill the second function, the roughness elements have to be high enough to intercept the particles as they bounce along the ground and into the air (saltate) and wide enough to act as an effective reservoir to store the trapped particles. Saltating particles seldom reach a height of 1 foot.

It is extremely difficult to evaluate the degree of surface roughness by measuring the height of surface obstructions. But ARS scientists have devised a "ridge roughness equivalent" based on wind-tunnel tests and on the height of ridges made with fine gravel 2 to 6.4 millimeter in diameter and with a height-spacing ratio of 1:4. If the gravel ridges are 4 inches high and 16 inches apart, a comparable field roughness would have a K factor of 4 inches, if the roughness were at right angles to the direction of the wind. Using this approach, ARS scientists have evaluated the ridge roughness of representative fields and made labeled photographs of them. Eighteen of these photographs appear at the end of this report. By comparing them with the field under study until a reasonable match emerges, the ridge roughness of the field can be approximated. The quantity of crop residue on each representative field also appears on the labels to help evaluate factor R.

Soil Abradability (F)

In the field, once erosion starts, it usually continues as long as the wind blows and may actually increase in intensity with distance downwind and with each subsequent wind. The eroding particles cut into the surface crust, thereby creating more and more erodible particles that in turn become abrasive.

Soils in wind tunnels do not react similarly because the erodible particles usually blow off the test area before they can appreciably cut into the surface crust and create additional abrasive particles.

Fine sand is the most susceptible of the soil texture classes to this cumulative abrasive action. Research shows that under field conditions its erodibility is 6 times greater than in a wind tunnel--6 is therefore its soil abradability factor. Similarly, loamy fine sand has a factor of 4; fine sandy loam and clay a factor of 2; and loam, silt loam, clay loam, and silty clay loam, a factor of 1. Using these respective factors changes the wind tunnel erodibility of the field under study to the natural surface erodibility.

Wind Velocity-Surface Soil Moisture Factor (C)

The evaluations of the preceding factors reflect the influence of wind velocity and surface soil moisture conditions prevailing at Garden City,

Kans., during the years 1954 through 1956. Similar conditions of the same maximum intensity are estimated to occur there on the average once in every 15 years. They may be therefore considered as standard conditions on which practices to control wind erosion in the Garden City area are designed, and as reference conditions for other regions.

But the intensity of practices required in other regions is different than at Garden City because wind velocity and surface soil moisture are different. The research objective is to design measures that would be equally effective in all regions where wind erosion is a problem.

To make the equation universally applicable, therefore, the climatic factor had to be worked out for every section of the United States where wind erosion is a problem. ARS scientists have done this by utilizing records from about 250 U. S. Weather Bureau stations and other sources. The various climatic factors thus worked out appear as percentages of the standard conditions and are read from a map.

Field Width (W)

The rate of soil movement on the windward side of an unprotected field is zero. From this point it increases more or less proportionately with distance downwind until, if the field is large enough, a maximum rate is reached. The distance required for soil flow to reach the maximum is the same for any wind velocity above 13 miles per hour, but varies only with the soil's natural erodibility. The more erodible the soil, the shorter the distance in which maximum flow is reached.

Maximum rate of soil flow for any wind is remarkably uniform for all field surfaces. It is equal to about 2 tons per rod width per hour for a 40-mile-per-hour wind 50 feet above an unsheltered, level terrain.

The increase in rate of soil flow with distance downwind across an unsheltered, wind-eroding area is called soil avalanching. It is due to the constant lift and drag of wind pulling upwards and sideways and to the cumulative abrasive effect of the blowing particles cutting into the surface crust and abrading stable aggregates into erodible particles.

Utilizing wind tunnel studies and actual measurements of rates of soil movement in eroding fields, ARS scientists have determined the distances at which soil movement first reaches a maximum for every possible change in natural field erodibility. Standard conditions were a series of erosive winds blowing at the rate of 40 miles per hour at a height of 50 feet.

Wind Direction (D)

Ideally, fields or strips are oriented in such a way that prevailing winds blow directly across them and not down, or parallel, to them. Blowing parallel to fields or strips, winds exploit the maximum distances available and so are more likely to induce maximum rates of soil movement than if restricted to the shorter width distances.

Winds striking fields or strips at an angle (obliquely) have the effect of increasing their widths and contributing to maximum rates of soil flow.

Since it is not always possible or practical to orient fields or strips exactly as desired, the angle at which winds strike any field must be considered when its erodibility is being studied. ARS scientists have worked out the effects of winds striking fields at any angle between 1° and 45° from the perpendicular and have prepared ready-reference charts to reflect these effects.

Wind Barriers (B)

Trees, hedges, tall stubble, and crops at right angles to the prevailing direction of the wind may effectively reduce the velocity of the wind and consequently reduce erosion. The horizontal distance that is completely protected from erosion by a 40-mile-per-hour wind on a highly erodible soil is roughly 10 times the barrier height. Some reduction in wind velocity occurs beyond this distance. This evaluation is an average based on many barrier studies under many conditions and is approximately comparable to the effect that a single row of evergreens or 1 or 2 rows of deciduous trees with leaves on, or about 7 to 10 rows of deciduous trees with leaves off, would have on the distance of full protection. The narrower the distance between barriers, the more the soil will be protected from wind erosion.

The distance of full protection afforded by short stubble is relatively small. It is usually disregarded and considered as only an additional safety factor. However, the protection that even short stubble gives to the ground it covers is considerable.

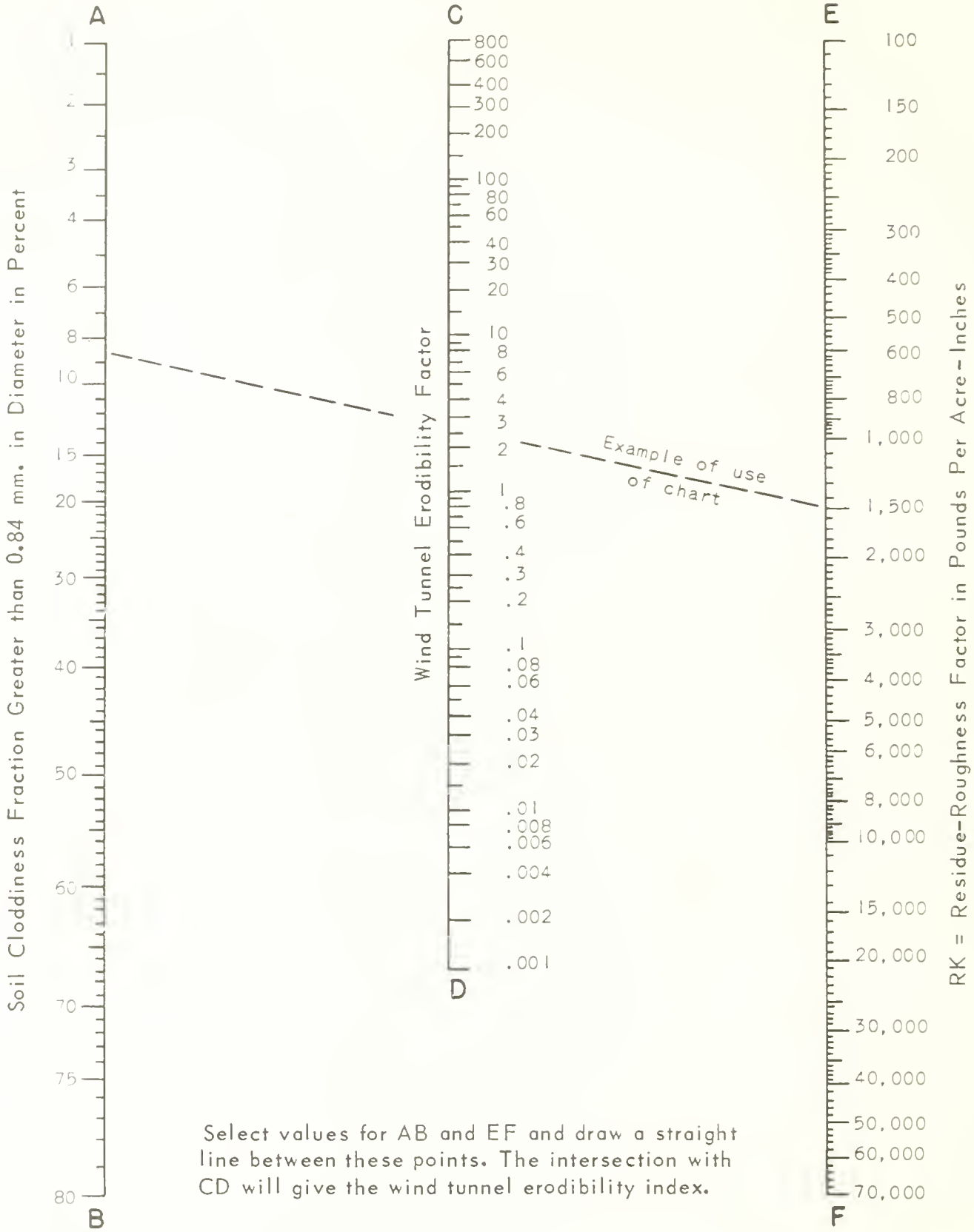
APPLICATIONS

The following explanations, charts, map, and photographs are intended primarily for those agricultural leaders who will use the universal wind erosion equation in the field. Any user, however, should realize that the ultimate accuracy of any erodibility determination depends on the accuracy with which the factors are evaluated. Care should be taken to follow outlined procedures as much as possible.

Wind Tunnel Erodibility

Figure 1 shows how wind tunnel erodibility is determined. After evaluations for soil cloddiness, amount of residue, and ridge roughness are made, the last two are multiplied together as indicated in column EF of the figure. When a straightedge connects this product with the soil cloddiness in line AB, the wind tunnel erodibility is read from the point where the straightedge crosses line CD. The dotted line in the figure illustrates this procedure. As indicated, a field with a residue-roughness factor of 1500 (for example, 300 pounds of residue per acre and a ridge roughness equivalent of 5 inches) and a soil cloddiness of about 8.6 percent would have a wind tunnel erodibility of about 2.5. This wind tunnel erodibility applies to 300 pounds of average standing residue. If the residue is other than standing, K and RK will be smaller and wind tunnel erodibility will be correspondingly greater. If the residue is wheat stubble, multiply RK by 1.33 and if it is sorghum stubble, multiply RK by 0.66 and then determine the wind tunnel erodibility. Thus, RK for 300 pounds per acre of wheat stubble will be 1500 x 1.33 = 2000 and for 300 pounds of sorghum stubble it will be 1500 x 0.66 = 1000. Therefore, using the chart as before we find that the wind tunnel erodibility is about 2.0 for 300 pounds of wheat stubble

ALIGNMENT CHART FOR WIND TUNNEL ERODIBILITY BASED ON ESSENTIALLY CRUSTED SURFACE SOIL



BN-12178-x

Figure 1.--Alinement chart for wind tunnel erodibility, based on crusted surface soil.

and 4.2 for 300 pounds of sorghum stubble. It takes about twice as much sorghum as wheat stubble to reduce wind tunnel erodibility to the same amount.

Natural Field Surface Erodibility

Erodibility determined from column "CD" of figure 1 measures wind tunnel erodibility regardless of the status of the surface crust. Wind tunnel erodibility can be converted to natural field surface erodibility by using the conversion factors in the table below for various soil textural classes. Natural field surface erodibility is a more true expression of what happens on a large field. If the soil were a loamy fine sand the factor would be 4, and 4 times 2.0 (wind tunnel erodibility for wheat stubble residue) would give 8 which is the natural field surface erodibility based on Garden City, Kans., climatic conditions.

Soil Textural Class	Conversion Factor (F)
Fine sand	6
Loamy fine sand	4
Fine sandy loam, clay, and very fine sandy loam	2
Loam, silt loam, clay loam, and silty clay loam	1

Relative Field Erodibility

Suppose the field with above-mentioned natural field surface erodibility of 8 based on Garden City, Kans., conditions is 1,000 feet wide along the east-west direction and much longer along the north-south. A hedge 10 feet high is on the west margin. The prevailing erosive wind is almost west-northwest--striking the field at an angle of 40°. The field is located in the vicinity of Norfolk, Nebr. The purpose is to determine the relative field erodibility.

Influence of Geographic Location

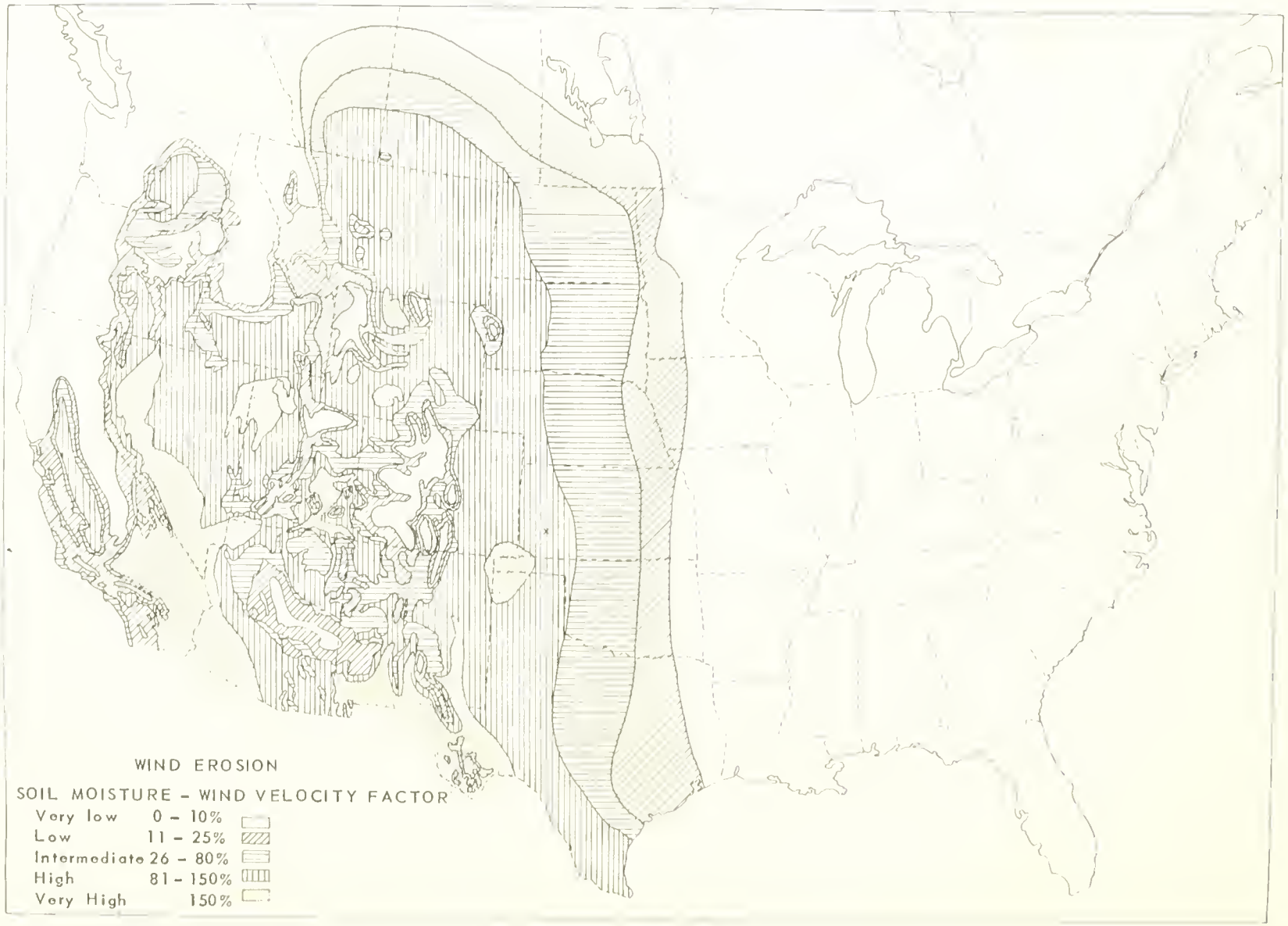
The map of figure 2 shows that the wind velocity-surface soil moisture factor for Norfolk, Nebr., is about 25 percent in terms of that at Garden City, Kans. Therefore, the natural field surface erodibility for this field is 25 percent of 8 = 2.

Influence of Wind Direction

If prevailing wind strikes the field at an angle more than 0° from the perpendicular (40° in this case), figure 3 must be consulted. When the straightedge connects 40 on column CD of figure 3 with 1,000 on column EF, the point where the straightedge cuts line AB is 1,300 feet. This is the width along prevailing direction of wind needed for field erodibility determination.

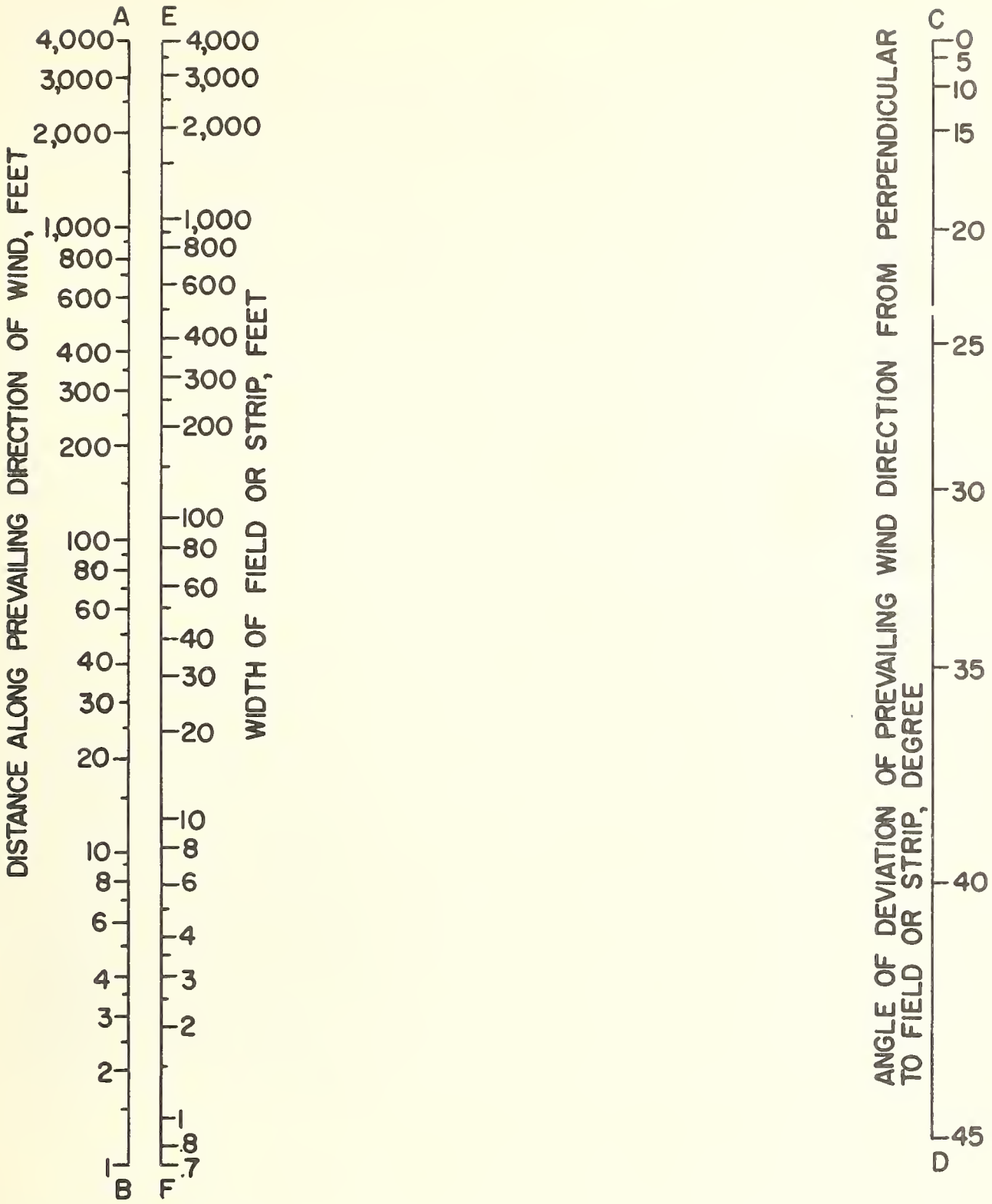
Influence of Barriers

A hedge 10 feet high fully protects the field 10 times its height or 100 feet along the direction of the prevailing wind. The unprotected portion of this field therefore is 1,300 - 100 = 1,200 feet along prevailing direction of wind.



BN-12176-x

Figure 2.--Map of the United States and southern Canada showing wind-velocity-surface soil moisture factor (expressing relative soil loss by wind as percentage of that in the vicinity of Garden City, Kans. (marked by X).



BN-12177-x

Figure 3.--Alinement chart for determining distance across field along prevailing direction of wind from the width of field and prevailing direction of wind.

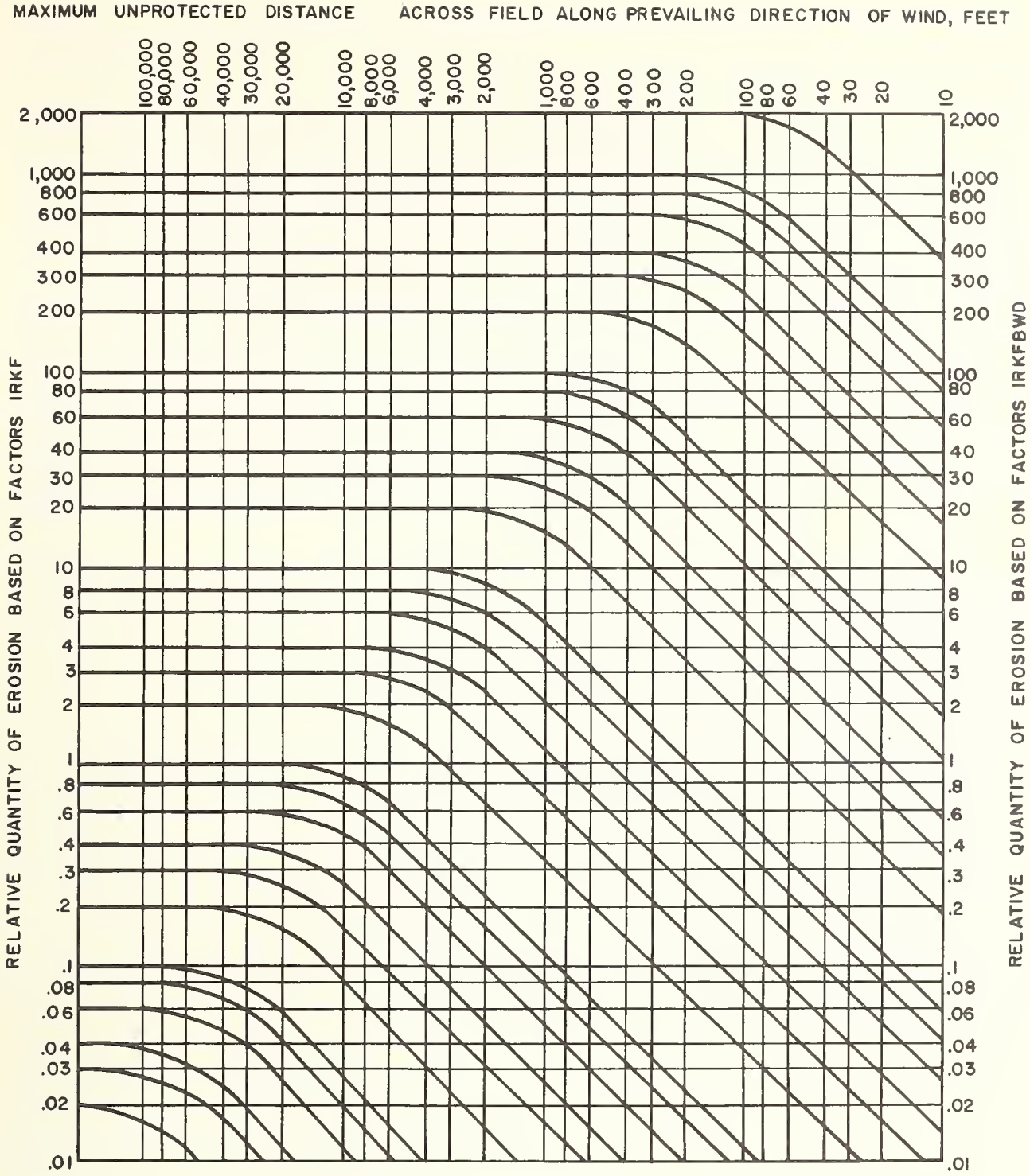
Influence of Width of Field

To determine the influence of field width on relative field erodibility, figure 4 is consulted. This determination is made in the following way: Locate 2 (the natural field surface erodibility IRKF for this field at Norfolk, Nebr.) on the far left, vertical line. From this point follow along the heavy line. Keep following the line as it dips down to the right. When the heavy line crosses the thin vertical line even with 1,200 at the top of the figure, lay a straightedge at this point and parallel with the thin, horizontal line immediately above. Where the straightedge cuts the far right vertical line is the relative field erodibility. It cuts the line at 0.37. This means that soil on this 1,000-foot-wide field that has a natural field surface erodibility of 2 has a relative field erodibility of 0.37. We should remember that the object is to reduce the field erodibility to an insignificant quantity of 0.1. Following along the same heavy line as before, we find that 0.1 is reached for the unprotected portion of the field that is only about 300 feet wide along prevailing direction of wind. Rather than narrowing the field that much, it would be easier to protect it with more crop residue and probably with greater surface roughness. It is doubtful that cloddiness can be increased greatly on this loamy sand. The farmer must use his ingenuity to devise an effective method of control. This analysis merely tells him that the field, as it is now, is too erodible and therefore something must be done to remedy the trouble.

We can determine the quantity of wheat residue the farmer will need on this field by working the charts and table in reverse, as follows: Start with the point in figure 4 corresponding to insignificant field erodibility of 0.1, shown on the right-hand side of the figure, and 1,200 feet, shown on top. Move between the heavy lines and to the extreme left side of the figure. The value on the extreme left is 0.9 which is the desired natural surface erodibility of this field under Norfolk, Nebr., conditions. The desired natural surface erodibility under Garden City conditions would be 0.9 ÷ 25 percent = 3.6. The wind tunnel erodibility for this loamy fine sand would be 3.6 ÷ 4 = 0.9. We should recall that this soil contains 8.6 percent of nonerodible clods. Placing a straightedge on figure 1 so that it passes through wind tunnel erodibility of 0.9 and cloddiness of 8.6 percent, we find that the average RK is equal to 3,600. But for wheat stubble residue, RK is 3,600 ÷ 1.33 = 2,700. If K for this residue is 4 inches, then the amount required is 2,700 ÷ 4 = 675 pounds per acre--more than double the 300 pounds per acre that is on the land at the present time. This is the quantity of wheat stubble residue the farmer will need on the field to prevent serious wind erosion.

RELATIVE FIELD ERODIBILITY vs. ANNUAL SOIL LOSSES

Soil losses under wind erosion are difficult to define and difficult to measure. A 5-ton per acre or less annual loss is tentatively chosen as an insignificant rate of soil loss. This corresponds to the relative field erodibility of 0.1. If the intensity of practices required to reduce the annual soil loss to 5 tons per acre is unattainable or too readily attainable in a practical way, the insignificant annual soil loss and relative field erodibility can be modified uniformly one way or another simply by raising or lowering them according to popular desire. The ARS scientists believe that the rate of annual soil loss tentatively chosen as insignificant is associated with reasonably good and uniform wind erosion protection everywhere.



BN-12179-x

Figure 4.--Chart showing the relationship between relative quantity of wind erosion and width of field along prevailing direction of erosive winds.

No technique has yet been devised to measure accurately absolute soil losses under wind erosion. The system devised by ARS scientists depended on the degree to which the roots and crowns of wheat were exposed and the differences between the distances to the tillage pan at the beginning and end of the blowing season. Using either standard, the scientists found it was impossible to measure depths of removal that were less than one-half inch. (If an acre lost soil to a uniform depth of one-half inch, the loss would be about 50 tons.) Because of these limitations, the values in the following table are highly approximate. They do show, however, how erosion damages winter wheat.

Relationships among quantity of wind erosion, effect of erosion, relative field erodibility, and annual soil loss.

Quantity of erosion	Description of erosion	Relative field erodibility	Annual soil loss*
			Tons per acre
None to insignificant	No distinct visible effects of soil movement	Less than 0.1	Less than 5
Slight	Soil movement not sufficient to kill winter wheat in boot stage	0.1 to 1.0	5 to 50
Moderate	Removal and associated accumulations to about 1-inch depth sufficient to kill wheat in boot stage	1.0 to 5	50 to 167
High	About 1- to 2-inch removal and associated accumulations	5 to 20	167 to 333
Very high	2- to 3-inch removal with small dune formations	20 to 150	333 to 500
Exceedingly high	More than 3-inch removal with appreciable piling into drifts or dunes	More than 150	More than 500

*Occurring in the vicinity of Garden City, Kans., during 1954 through 1956.

PHOTOGRAPHS FOR ESTIMATING FACTORS K AND R

BN 12162-x

1. Loose, blowing sand, surface practically bare and smooth. K=1.0 inch. R=312 pounds per acre.

BN 12168-x

2. Smooth, fallow surface, beaten down by rain, practically bare. K=1.5 inches. R=224 pounds per acre.

BN 12163-x

3. Good wheat residue cover, flattened down with one-way disk. K=1.6 inches. R=425 pounds per acre.

BN 12165-x

4. Loose surface of loamy sand with same grass. K = 2.0 inches. R = 311 pounds per acre.

BN 12160-x

5. Smooth surface with very sparse sarghum stubble. K = 2.0 inches. R = 400 pounds per acre.

BN 12161-x

6. Smooth surface with very short, thin, sarghum stubble. K = 2.5 inches. R = 245 pounds per acre.

BN 12159-x

7. Semideep, furrow drill ridges with some wheat stubble. K = 2.6 inches. R = 790 pounds per acre.

BN 12164-x

8. Good stand of growing wheat, about 3.5 inches high, slightly ridged by drill. K = 3.2 inches. R = 779 pounds per acre.

BN 12167-x

9. Heavy stubble from combined wheat, partly flattened by one-way disk. K = 4.0 inches. R = 3,980 pounds per acre.

BN 12172-x

10. Cotton, machine-stripped. K = 4.3 inches. R = 1,090 pounds per acre.

BN 12170-x

11. Stubble, from sorghum cut with binder, 5 to 7 inches high, 40-inch rows. K = 4.35 inches. R = 575 pounds per acre.

BN 12173-x

12. Stubble, from combined wheat, 8 to 10 inches high. K = 4.4 inches. R = 1,090 pounds per acre.

BN 12171-x

13. Sorghum stubble, surface chiseled, with some large clods, considerable drifting. K = 4.6 inches. R = 640 pounds per acre.

BN 12174-x

14. Recently plowed land with cloddy and moderately rough surface. K = 4.0 inches. R = 100 pounds per acre.

BN 12158-x

15. Stubble, from combined sorghum, 10 to 12 inches high, 40-inch rows. K = 6.3 inches. R = 1,220 pounds per acre.

BN 12175-x

16. Heavy sorghum stubble on irrigated land, thick and leafy, 8 to 10 inches high, 40-inch rows. K = 8.5 inches. R = 1,890 pounds per acre.

BN 12166-x

17. Listed, little or no residue on surface. K = 10.1 inches. R = 155 pounds per acre.

BN 12169-x

18. Stubble, from irrigated milo combined for grain, 16 to 18 inches high. K = 12.5 inches. R = 2,275 pounds per acre.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1961 O - 596815

UNITED STATES DEPARTMENT OF AGRICULTURE

1862 1962

Growth Through Agricultural Progress